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Means for limiting an output signal of an amplifier stage

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Means for limiting an output signal of an amplifier stage

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The invention relates to an electronic circuit comprising an amplifier stage having an input for receiving an input signal and an output for supplying an output signal, whereby, during operation, the strength of the output signal increases in response to an increasing strength of the input signal as long as the strength of the input signal has not exceeded an input reference level.

Such an electronic circuit is known from the general state of the art. In numerous electronic systems amplifiers are needed to amplify a signal. Generally a relatively small input signal is converted into a relatively large output signal. In many occasions the amplifier comprises several amplifier stages. Sometimes the dynamic range of the input signal is very large. This can cause an overdrive of one or more of the amplifiers stages. This is not always a serious problem. In fact in many applications it is appreciated that relatively large input signals can not be amplified into output signals larger than a certain desired level. When an amplifier stage is overdriven, this causes one or more bipolar transistors (if implemented in the amplifier stage) to go into saturation, or causes one or more field effect transistors (if implemented in the amplifier stage) to go out of saturation. If the input signal decreases after such an overdrive has occurred, the amplifier should quickly recover in order to fully amplify the weaker input signal within a short amount of time. However bipolar transistors need some time to come out of saturation, and field effect transistors need some time to get into saturation again. For this reason the amplifier needs some time to recover. There are applications which require a very short recovery time of the amplifier. A very good way to guarantee a very short recovery time is to provide the amplifier with clipping means implemented in such away that the transistors which might influence the recovery time can not go out of there normal biasing, that is to say: bipolar transistors will never go into saturation, and field effect transistors will never go out of saturation.

US patent 6,108,293 discloses an optical disk recording device for conducting reading and recording of data through irradiation of laser beam on an optical disk medium. The device comprises a photo detection circuit for receiving input of reflected light from an optical disk medium to detect a reproduced signal. An amplifier amplifies the reproduced signal and outputs the amplified reproduced signal for monitoring. During recording mode

high intensity laser pulses are focussed on the optical disk medium. In between these pulses also information (like in reading mode) must be read in order to acquire tracking information and e.g. a so called wobble signal. The high density laser pulses cause a relatively high amplitude of the signal from the photo detection circuit which is put into the amplifier. This
5 may overdrive the amplifier. As a consequence the recovery time of the amplifier may be too long. A way to overcome this problem is proposed by the addition of current subtracting

means which subtracts current away from the photo detection circuit under control of a so called recording gate signal. An alternative solution is proposed whereby a gain control circuit is added in between the photo detection circuit and the amplifier. Then also the gain of
10 the gain control circuit is set under control of a recording gate signal.

A disadvantage of both proposed solutions is that they need additional information (e.g. the recording gate signal) and additional circuitry in order to avoid an overdrive of the amplifier. In other words the amplifier can not autonomously perform its amplifying task without the danger of being overdriven.

15 Therefore it is an object of the invention to provide an electronic circuit which can autonomously handle an input signal having a relatively large dynamic range without being overdriven.

To this end, according to the invention, the electronic circuit of the type defined in the opening paragraph is characterized in that the strength of the output signal is
20 approximately kept constant when the strength of the input signal has exceeded the input reference level but has not exceeded a further input reference level, and that the strength of the output signal decreases in response to an increasing strength of the input signal when the strength of the input signal has exceeded the further input reference level.

By proper definition of the input reference level an overdrive of the amplifier
25 stage can be avoided. By proper definition of the input reference level is meant that input signals having an amplitude which are not higher than the input reference level will be amplified by the amplifier stage in a normal mode (usually this means a more or less linear amplification), that is to say without clipping. The amplifier stage is dimensioned in a way that the transistors which might influence the recovery time of the amplifier stage keep in
30 their normal biasing, that is to say they will not undesirably go into or out of saturation in this normal mode. When the amplitude of the input signal is larger than the input reference level, but still not larger than the further input reference level, the amplifier stage is in a clipping mode. In the clipping mode the output signal is kept constant. The clipping is performed in a manner that the transistors of the amplifier stage keep in their normal biasing.

In principal the inventive electronic circuit may have only one amplifier stage. Usually, however, a multiple of amplifier stages are used. If for instance two amplifier stages are used it may be sufficient that only the first amplifier stage is provided with the said clipping means. After all, in this situation, the amplitude of the output signal of the first amplifier stage, which forms the input signal of the second amplifier stage, is already clipped when the amplitude of the input signal has exceeded the input reference level. However, it is to be emphasized that it is not necessary that the inventive amplifier stage should always be the first stage. Further several inventive amplifier stages may be applied.

When the amplitude of the input signal is larger than the further input reference level, the amplifier stage is in a fold-back mode, that is to say that the amplitude of the output signal is no longer kept constant, but is decreasing with a further increasing amplitude of the input signal. This has the advantage of a reduced power consumption of the electronic circuit.

An embodiment of the invention is characterized in that the strength of the output signal can not become lower than an output reference level when the strength of the input signal has exceeded the further input reference level. By this it is avoided that current through transistors in the amplifier stage can become very low, e.g. zero. This prevents transistors to react slowly. If the output signal has reached the said output reference level, this situation will be further denoted as the minimum fold-back mode. Thus the recovery time of the amplifier from the (minimum) fold-back mode into the normal mode is further decreased. Also any other amplifier stages following the inventive amplifier stage will recover more quickly.

An embodiment of the invention is characterized in that the further input reference level is approximately equal to the input reference level. This means that the so called clipping mode is now not present. Thus when the amplitude of the input signal exceeds the input reference level the amplifier immediately turns into the fold-back mode. This has the advantage that the average power consumption of the amplifier stage is further reduced. Another advantage is the somewhat less complex implementation of the amplifier stage.

The presence of a clipping mode can however be advantageous. If for instance the dynamic range of the input signal is such that it just does not exceed the input reference level, then by the presence of some noise, which is unfortunately always present in a signal, the input reference signal may be exceeded during the positive values of the noise and not during the negative values of the noise. This causes a distortion of the output signal because then HF-noise can be converted into LF-noise. Also a DC-component is introduced by this

clipping. If however in such a situation there would be no clipping mode the amplifier would turn into the fold-back mode during the positive values of the noise. This causes the same distortion as previously described, but on a much higher level. Thus it depends on the design parameters of the electronic circuit whether it is desirable or not to implement a clipping mode in the amplifier stage.

An embodiment of the invention is characterized in that the input signal is an input current, and the output signal is an output current. In practice the invention can most easily be implemented in the current domain. Then the core of the amplifier stage can be implemented by a (simple) current mirror which may have a current mirror gain factor.

Alternatively the invention can however also be implemented in the voltage domain. This is even possible when the input signal is a current, and an output signal of the electronic circuit is also a current. It is then possible to put the input signal into a current-to-voltage converter, apply the inventive principles in the voltage domain, and then convert the voltage back into a current by a voltage-to-current converter.

An embodiment of the invention, whereby the input and output signals of the amplifier stage are currents, is characterized in that the amplifier stage comprises a first current path coupled between the input and a common node; a second current path coupled between the output and the common node; first control means coupled between the input and the common node, for controlling a voltage on the common node and for supplying a current to the common node, the first control means comprising limiting means for limiting the current to the common node when the strength of the input signal has exceeded the input reference level; and second control means for supplying a compensation current to the input when the strength of the input signal has exceeded the input reference level. The first and second current paths form together a current mirror. Usually a current mirror has an input, an output, and a common reference which is usually connected to a power supply terminal. In this case the input of the so formed current mirror is in fact the input of the amplifier stage, and thus receives current from a signal current source. The output of the current mirror is in fact the output of the amplifier stage. The common reference, which is denoted as the common node, is in this invention not connected to a power supply terminal but to the first control means. This enables the possibility of not only controlling the voltage at the common node, but also to limit the maximum current to the common node. If the input current becomes larger than the input reference level, then the current to the common node is limited by the limiting means within the first control means. In that situation the current from the signal current source can no longer be fully put into the input of the amplifier stage. This

would cause a saturation situation of the signal current source, whereby the signal current source is forced to deliver less current. Generally this is an unfavorable situation. This situation is however avoided by the presence of the second control means which supplies a compensation current to the input when the strength of the input signal has exceeded the input reference level.

An embodiment of the invention is characterized in that the amplifier stage further comprises a third current path having a first side coupled to the input, and a second side coupled to the second current path for taking away current from the second current path so that the strength of the output current decreases in response to an increasing strength of the input signal when the strength of the input signal has exceeded the further input reference level. This is an example of an implementation of the fold-back mode. The taking away of the part of the current is not accomplished by a separate current means but by using (part of) the residue part of the current delivered by the signal current source. This reduces the power consumption of the amplifier stage.

An embodiment of the invention is characterized in that the amplifier stage further comprises a fourth current path coupled to the second current path for supplying current to the second current path in order to avoid that the output current can be lower than the output reference level when the strength of the input signal has exceeded the further input reference level. This is an example of an implementation of the minimum fold-back mode. The coupling of the fourth current path to the second current path may coincide with the second side of the third current path. This is however not a necessity.

The invention also relates to an optical/magneto-optical disc recording apparatus. An inventive optical/magneto-optical disc recording apparatus having a light source for storing data on a disk, and light receiving means for the detection of data from the disk, is characterized in that it comprises the inventive electronic circuit whereby the input signal of the amplifier stage is responsive to a signal delivered by the light receiving means.

The light source is usually a laser. Light pulses with a high intensity are used to write data on an optical disk. Such a disk is for instance a CD (Compact Disk), DVD (Digital Versatile Disk), or BD (Blu-ray Disk, in earlier days indicated by DVR). The apparatus comprises a so called PDIC (Photo Diode Integrated Circuit) which is an IC having (pre-)amplifiers and integrated photo diodes, the latter function as the light receiving means for the detection of data from the disk. The PDIC is used to monitor the reading/writing process. In order not to overdrive the PDIC during the writing process a low amplifier gain is needed. However also the signal parts in between the high intensity light pulses must be read

because they contain servo information, track addresses, and a wobble signal. These signal parts can however not be processed with a low amplifier gain because these signals parts would then drown in offset and noise. This is because these signal parts have in fact a small amplitude (comparable with the amplitude of the signal during the reading process). Thus a high amplifier gain is needed.

Thus during the writing process on the one hand a high amplifier gain is needed for the processing of the weak signal parts in between the high intensity light pulses, and on the other hand a low amplifier gain is needed to monitor the (reflected) high intensity light pulses without overdriving the PDIC. In theory it is possible to switch between a low and a high gain path. In practice this turns out to be difficult to implement because it imposes very high settling requirements on amplifiers stages.

By the implementation of the inventive electronic circuit this difficulty is overcome because it comprises the inventive amplifier stage which can handle a very large dynamic range of the input signal without being overdriven.

The inventive electronic circuit can be advantageously applied in all electronic systems which need means to limit an output signal and which need a very short recovery time when the relatively strong input signal is reduced to a relatively weak input signal. So the electronic circuit can for instance be used in the high frequency part of a receiver (like radio, television) whereby clipping of strong signals does not cause distortion of the information. So for instance when frequency or phase modulation is used. If the receiver is of the very commonly used "super heterodyne type" then the inventive amplifier stage can also be implemented in the so called intermediate frequency part.

The invention also includes a method whereby an input signal is being converted to an output signal, and whereby the strength of the output signal increases in response to an increasing strength of the input signal as long as the strength of the input signal does not exceed an input reference level, and whereby the strength of the output signal is being kept approximately constant when the strength of the input signal exceeds the input reference level but does not exceed a further input reference level, and whereby the strength of the output signal decreases in response to an increasing strength of the input signal when the strength of the input signal exceeds the further input reference level.

Optionally the further input reference level may be chosen to be equal to the input reference level. This has the effect that the output signal immediately decreases in response to an increasing strength of the input signal when the strength of the input signal has exceeded the input reference level.

An embodiment of the inventive method is characterized in that the strength of the output signal does not become lower than an output reference level when the strength of the input signal exceeds the further input reference level.

5 The invention will be described in more detail with reference to the accompanying drawings, in which:

Figure 1 shows a simplified schematic of an optical disk drive apparatus in which the invention can be advantageously applied;

10 Figure 2 show different gain paths for the handling of a signal from photo diodes;

Figure 3 shows a signal diagram of the laser light power and the reflected laser light power of the optical disk drive apparatus during recording mode;

Figures 4 and 5 show signal diagrams for explaining the principles of the invention;

15 Figures 6 and 7 show schematics showing parts of an inventive amplifier stage for giving an introductory explanation of the invention in broad terms;

Figure 8 shows an embodiment of the inventive amplifier stage in broad terms;

Figures 9 - 13 show detailed electronic schematics of parts of the inventive amplifier stage; and

20 Figures 14 -16 show detailed electronic schematics of embodiments of the inventive amplifier stage.

In these figures parts or elements having like functions or purposes bear the same reference symbols.

25 Figure 1 shows a simplified schematic of an optical disk drive recording/reading apparatus comprising a light source LS, a half-prism HP, an objective lens OL, photo diodes PHDS, and electronic processing means PR.

30 During a reading mode information stored on an optical (or magneto-optical) disk DSK must be retrieved. The light source LS, which is usually a laser device, radiates a light beam which passes partly through the half-prism HP. The light is then focussed on an information layer of the DSK by the objective lens OL. The information layer may comprise so called pits and lands. These pits and lands are in fact logic "0" and "1" 's representing the information. Thus the information is stored in a binary (and digital) form. Light which lands on a land is highly reflected backwards. Light which lands on a pit is also reflected

backwards, but to a lesser degree. Therefore the stored logic "0" and "1" 's can be retrieved by detection of the reflected light from the disk DSK. The reflected light is partly mirrored and is received by light receiving means. The light receiving means are by way of example implemented by the photo diodes PHDS. Usually the photo diodes PHDS comprise several parts for delivering separate signals to the processing means PR. In this example the photo

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diodes PHDS comprise 4 parts, and thus 4 separate signals A, B, C, and D are delivered. In many cases the photo diodes PHDS and the processing means PR are constructed in a single IC (integrated circuit) which is often denoted as PDIC (Photo Diode Integrated Circuit). The processing means PR retrieves the information (usually) by the summation of the 4 signals A, B, C, and D. Also other information is acquired by various combinations of the 4 signals A, B, C, and D. Thus also servo information, track addresses, wobble signals, etcetera can be retrieved in this manner.

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There are several ways to register information on the disk during recording (writing) mode. In stead of using the method of really creating pits and lands, which method is normally used during the manufacturing of ROM-disks, other methods are normally used for recordable disks. The disk DSK is for instance provided with a dye which partly reflects light. During recording the reflectivity of the dye reduces as a result of the focussing of high intensity laser pulses L_1 (see figure 3) on the optical disk DSK. By this logic "0" and "1" 's can be stored and can (later) be retrieved by detection of the reflected light from the disk DSK. In stead of using a dye as information layer of the disk DSK also other principles for registering information can be applied, for instance the so called "phase change principle". In this latter principle a crystalline material is converted into an amorphous material (or vice versa) as the result of the focussing of the high intensity laser pulses L_1 on the optical disk DSK.

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The recording mode will be further explained with reference to figures 1 and 3. High intensity laser pulses L_1 are focussed on the optical disk DSK. The maximum value of the laser Power LP of the laser pulses L_1 is indicated as WL ("Write Level"). The reflected light power is indicated by light "pulse" L_2 . During a laser pulse L_1 the reflected light "pulse" L_2 decreases. See for instance the time period between time instants t_1 and t_2 . This enables the possibility of controlling the reflectivity by measuring the reflected light "pulses" L_2 . In between the laser pulses L_1 also information (like in reading mode) must be read in order to acquire tracking information, etcetera. So this information is for instance read between time instants t_2 and t_3 . The value of the laser Power LP of the laser pulses L_1 is then much less. This value is indicated as RL ("Read Level").

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Thus during recording mode reflected light with high intensity as well as reflected light with low intensity must be processed by the processing means PR. As a consequence the dynamic range of one or more of the 4 signals A, B, C, and D can be very high. This can cause problems with amplifiers stages implemented in the processing means PR, because it imposes very high settling requirements on the amplifiers stages. For further elucidating this problem, which is solved by the application of the invention, reference is now also made to figure 2. By way of example only the signal A delivered by the photo diodes PHDS is further contemplated. Henceforth only the recording mode of the optical disk drive apparatus will be contemplated.

Figure 2 shows a first gain path G_{PTH1} having a relatively high gain factor G_1 , and a second gain path G_{PTH2} having a relatively low gain factor G_2 . The first gain path G_{PTH1} serves to amplify the weak signals (on "RL" level) in between the high intensity laser pulses L_1 . The second gain path G_{PTH2} serves to amplify the reflected light "pulses" L_2 which have a much larger intensity. During the processing of the strong signals, for instance between time instants t_1 and t_2 , one or more amplifier stages in the first gain path G_{PTH1} will be overdriven. This causes, except when special measures are taken, one or more bipolar transistors (if implemented) to go into saturation, or causes one or more field effect transistors (if implemented) to go out of saturation. If the amplitude of signal A decreases after such an overdrive has occurred, for instance between time instants t_2 and t_3 , the first gain path G_{PTH1} should quickly recover in order to fully amplify the weak signal A within a short amount of time. However bipolar transistors need some time to come out of saturation, and field effect transistors need some time to go into saturation again. For this reason the first gain path G_{PTH1} needs some time to recover. This recovery time reduces the maximum recording speed of the optical disk drive apparatus, and is thus undesirable.

By the application of the inventive electronic circuit having at least one inventive amplifier stage which is implemented in the first gain path G_{PTH1} , the maximum recording speed can be increased significantly.

Figure 4 shows a signal diagram for explaining the principles of the invention. The signal diagram represents the signal transfer function G_1 of an inventive amplifier stage whereby the signal A forms the input signal of the amplifier stage and $G_1 \cdot A$ is the output signal of the amplifier stage. As long as the amplitude of the input signal A is no larger than an input reference level I_A the amplifier stage is in a so called normal mode. The output signal $G_1 \cdot A$ is then approximately constant in this example. Thus the input signal A is linearly amplified. (It is however to be noted that a linear amplification in this normal mode,

although in many applications desirable, is not a necessity.) The value of the input reference level I_A must be chosen such that it is equal or higher than the maximum amplitude of the weak signals (on "RL" level) in between the high intensity laser pulses L_1 .

During a laser pulse L_1 the reflected light "pulse" L_2 which is now represented
5 by the input signal A has an amplitude which is larger than the input reference level I_A .
(These reflected light "pulses" L_2 are monitored via the second gain path $GPTH_2$.) If the
amplitude is however not larger than a further input reference level I_B the amplifier stage is in
a so called clipping mode. The output signal $G_1 \cdot A$ is then approximately kept constant in this
example. If the amplitude of the input signal A exceeds the further input reference level I_B
10 the amplifier stage is in a so called fold-back mode. Preferably, in the fold-back mode, a
minimum value for the amplitude of the output signal $G_1 \cdot A$ must be set. This minimum
value is denoted as an output reference level I_{omn} . When the amplitude of the input signal A
is so strong that the amplitude of the output signal has reached the output reference level
 I_{omn} , the amplifier stage is in a so called minimum fold-back mode. Thus this occurs when
15 the input signal A exceeds an even further input reference level I_C .

Figure 5 shows a signal diagram which differs from the signal diagram as
shown in figure 4 in that the further input reference level I_B equals the input reference level
 I_A . The amplifier stage then immediately turns into the (minimum) fold-back mode when the
input signal A exceeds the input reference level I_A .

20 Figure 6 shows an amplifier stage AMPST comprising a current mirror CM
having an input IP, an output OP, and a common node cn. The current mirror CM comprises
a first current path CP_1 coupled between the input IP and the common node cn and a second
current path CP_2 coupled between the output OP and the common node cn. The amplifier
stage AMPST further comprises first control means FCM which comprises limiting means
25 LMT. The first control means FCM is connected between the input IP and the common node
cn. An input current source J_S which supplies a current I_i is connected to the input IP. The
input current source J_S represents for example the photo diodes PHDS (see figure 1) whereby
the current I_i represents a combination of the 4 signals A, B, C, and D, for instance the signal
A. The first control means FCM controls a voltage V_{cn} on the common node cn and supplies
30 a current I_2 to the common node cn. The current I_2 supplies current to the first and seconds
current paths CP_1 and CP_2 . Since, in this example, an input current I_i of the first control
means FCM equals zero the value of the current in the first current path CP_1 equals the value
of the current I_i . The current I_o in the second current path CP_2 forms the output current of the
amplifier stage AMPST.

If the amplifier stage AMPST is in the normal mode the current I_i is (linearly) amplified into the output current I_o . The value of the amplification is determined by a so called current mirror ratio which is defined by the current paths CP_1 and CP_2 . When the amplifier stage AMPST enters the clipping mode (or the fold-back mode in the situation as shown in figure 5) the limiting means LMT limits the value of the current I_2 . This occurs when the amplitude of the input signal I_i exceeds the input reference level I_A (see figures 4 and 5). As a consequence both the currents I_i and I_o are limited. The maximum value for the current I_o corresponds to the value $I_{o_{mx}}$ as indicated in figures 4 and 5. Because also the current I_i is limited (and the current I_1 equals zero) the input current is also limited and is thus no longer fully dictated by the current source J_S . It in fact means a saturation situation of the signal current source J_S .

Figure 7 shows an amplifier stage AMPST which differs from the one shown in figure 6 in that it further comprises second control means SCM for supplying a compensation current I_{cmp} to the input IP when the strength of the input signal I_i has exceeded the input reference level I_A . By this the said saturation situation of the signal current source J_S is prevented.

Figure 8 shows an amplifier stage AMPST which differs from the one shown in figure 7 in that it further comprises a third current path CP_3 having a first side coupled to the input IP, and a second side coupled to the second current path CP_2 ; and a fourth current path CP_4 coupled to the second current path CP_2 .

The third current path CP_3 takes away current from the second current path CP_2 so that the amplitude of the output current I_o decreases in response to an increasing strength of the input signal I_i when the amplifier stage AMPST is in the fold-back mode. This occurs when the amplitude of the input signal I_i has exceeded the further input reference level I_B (see figures 4 and 5).

The fourth current path CP_4 supplies current to the second current path CP_2 when the amplitude of the input signal I_i has exceeded an even further input reference level I_C (see figures 4 and 5). By this the minimum fold-back mode is implemented in which the value of the output current I_o can not become lower than the output reference level $I_{o_{mn}}$.

Figure 9 shows an electronic circuit comprising an amplifier stage AMPST which comprises the first control means FCM and the current mirror CM having the input IP, the output OP, and the common node cn. The amplifier stage AMPST is powered by a voltage source V_S which is connected between a first power supply terminal V_{DD} and a second power supply terminal V_{SS} of the amplifier stage AMPST. Input and output currents

of the amplifier stage AMPST are denoted as I_i and I_o , respectively. The current mirror CM comprises bipolar transistors T_1 and T_2 , each having a base, an emitter, and a collector; resistors R_1 and R_2 ; and capacitors C_1 and C_2 . The bases of transistors T_1 and T_2 are connected with a reference terminal B_{RF} . A voltage source V_1 is connected between the reference terminal B_{RF} and the second power supply terminal V_{SS} . The collectors of transistors T_1 and T_2 are connected with the input IP and output OP, respectively. The resistor R_1 is connected between the common node cn and the emitter of transistor T_1 . The resistor R_2 is connected between the common node cn and the emitter of transistor T_2 . The capacitor C_1 is connected between the common node cn and the collector of the transistor T_1 . The capacitor C_2 is connected between the common node cn and the collector of the transistor T_2 . Transistor T_1 and resistor R_1 (and optionally also capacitor C_1) form together the first current path CP_1 . Transistor T_2 and resistor R_2 (and optionally also capacitor C_2) form together the second current path CP_2 .

The first control means FCM comprises bipolar transistor T_3 having a base, an emitter, and a collector; field effect transistor M_1 , having a gate, a source, and a drain; resistor R_3 ; current source J_1 ; and buffer VB1, having an input and an output. The drain of transistor M_1 is connected with the first power supply terminal V_{DD} . The gate of transistor M_1 is connected with the input IP. The resistor R_3 is connected between the source of transistor M_1 and the second power supply terminal V_{SS} . The base of transistor T_3 is connected with the source of transistor M_1 . The emitter of transistor T_3 is connected with the second power supply terminal V_{SS} . The input of buffer VB1 is connected with the collector of transistor T_3 . The output of buffer VB1 is connected with the common node cn. The current source J_1 is connected between the first power supply terminal V_{DD} and the input of the buffer VB1.

The voltage source V_1 serves to supply a DC-biasing voltage at the bases of transistors T_1 and T_2 . Transistor M_1 and resistor R_3 form together a so called source follower. The current mirror CM, the source follower, transistor T_3 which is biased by the current source J_1 , and the buffer VB1 form together a so called feedback loop. This feedback loop controls the voltage V_{cn} at the common node cn. It also controls the current I_2 to the common node cn. The collector current of transistor T_1 equals the input current I_i . Preferably, the current mirror CM is dimensioned as follows: the emitter area of transistor T_2 is M times as large as the emitter area of transistor T_1 , the value of resistor R_1 is M times as large as the value of resistor R_2 , and the value of capacitor C_2 is M times as large as the value of capacitor C_1 . Capacitors C_1 and C_2 improve the HF-behaviour of the current mirror CM. If the output OP is terminated with a relatively low impedance, especially for HF, (for instance because it

is coupled to another current mirror) then the value of the output current I_o is approximately M times as large as the value of the input current I_i . (M may be smaller, equal, or larger than 1.) The limiting of the current I_2 , in order to create the clipping mode, is carried out by the buffer VB1.

Figure 10 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 9 in that it further comprises a buffer VB2 having an input connected to the collector of transistor T_3 , and an output, and in that the capacitor C_1 is connected to the output of the buffer VB2 in stead of to the common node cn. Further an implementation of the buffer VB1 is disclosed.

The buffer VB1 comprises an OTA (operational transconductance amplifier) having a non-inverting input connected to the collector of transistor T_3 , an inverting input connected to the common node cn, and an output; fourth, fifth, and sixth bipolar transistors $T_4 - T_6$ each having a base, an emitter, and a collector; a voltage source V_2 connected between the base of transistor T_6 and the second power supply terminal V_{SS} ; a current source J_2 connected between the emitter of transistor T_4 and the second power supply terminal V_{SS} ; and current source J_3 connected between the first power supply terminal V_{DD} and the emitter of transistor T_5 . The collectors of transistors T_5 and T_6 are connected to the second power supply terminal V_{SS} . The emitter of transistor T_6 and the base of transistor T_4 are connected to the output of the OTA. The base of transistor T_5 is connected to the emitter of transistor T_4 . The emitter of transistor T_5 is connected to the common node cn. The collector of transistor T_4 is connected to the first power supply terminal V_{DD} .

Bipolar transistors T_4 and T_5 , together with current sources J_2 and J_3 which supplies current through the transistors T_4 and T_5 , and the OTA form together a so called improved "emitter follower". (The improvement means the operation of the "emitter follower" even at very low currents.) The current source J_3 also supplies the current I_2 to the common node cn. In the normal mode a voltage V_C at the collector of transistor T_3 equals the voltage V_{cn} at the common node cn. In this example the limiting means LMT within the first control means FCM is performed by the current source J_3 .

During the clipping mode the voltage at the non-inverting input, the inverting input, and the output of the OTA raises significantly. In order to prevent a saturation situation of the OTA, the maximum voltage at the output of the OTA is limited by the presence of transistor T_6 and the voltage source V_2 . This is because the transistor T_6 will significantly conduct current if its base-emitter voltage is more than approximately 0.6 V. (This voltage may be a little bit different depending on the type of transistor used.) So if for instance it is

undesirable that the voltage on the output of the OTA exceeds 2.5 Volt, then the voltage which must be supplied by the voltage source V_2 may not be larger than 1.9 Volt (2.5 Volt - 0.6 Volt).

For HF the buffer VB1 is bypassed by the buffer VB2 and the capacitor C_1 . By this the feedback loop is kept stable, that is to say no slew rate oscillations will occur, during the clipping mode, and also not during the normal mode when the amplifier stage has come out of the clipping mode.

Figure 11 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 10 in that it further comprises second control means SCM comprising bipolar transistors T_{8a} and T_{8b} , each having a base, an emitter, and a collector; a voltage source V_3 ; and a voltage source V_4 . The emitters of transistors T_{8a} and T_{8b} are connected to the collector of transistor T_3 . The collector of transistor T_{8a} is connected to the second power supply terminal V_{SS} . The collector of transistor T_{8b} is connected to the input IP. The bases of transistors T_{8a} and T_{8b} are connected to each other. The voltage source V_3 is connected between the reference terminal B_{RF} and the bases of transistors T_{8a} and T_{8b} . The voltage source V_4 is at one side connected to the inverting input of the OTA and the emitter of transistor T_5 , and at another side connected to the current source J_3 and the common node cn.

The purpose of the additional components with regard to the circuit of figure 10 is as follows. When the amplifier stage AMPST enters the clipping mode the so called small signal loop gain of the feedback loop drops to a very low value. Without the presence of the second control means SCM the voltage VC would tend to raise towards the potential at the first supply terminal V_{DD} . This would turn the current source J_1 into saturation. This is however prevented by the second control means SCM. When the voltage VC exceeds a certain value the transistors T_{8a} and T_{8b} start to conduct current. This has the effect that the raise of the voltage VC is restrained. The collector current of transistor T_{8b} is used as the compensation current I_{cmp} (see figures 7 and 8). The dimensioning of the transistors T_{8a} and T_{8b} (e.g. the emitter ratio $a_x/b_x = a/b$ as indicated in figure 11), and the voltage delivered by the voltage source V_3 is, preferably, such that the input reference level I_A (see figures 4 and 5) is still determined by the current I_2 . With the presence of the voltage source V_4 the voltages V_{cn} and the voltage VC can be chosen different. Thus a higher degree of flexibility in dimensioning the amplifier stage AMPST is thereby enabled.

The second control means SCM in fact reduces the small signal loop gain of the feedback loop when the amplifier stage AMPST enters the clipping mode. The amount of

reduction of the small signal loop gain is determined by the emitter ratio a/b . The higher the emitter ratio a/b , the higher the reduction of the small signal loop gain. A high reduction of the small signal loop gain is favorable with respect to the stability of the feedback loop. It therefore also reduces HF-peaking in the transfer (current gain) of the amplifier stage AMPST. However, if the emitter ratio a/b is chosen too high then the current flowing through transistor T_3 will be too low, e.g. equal to zero. This would undesirably increase the recovery time of the amplifier stage AMPST.

Figure 12 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 11 in that it further comprises a bipolar transistor T_9 having a base, an emitter connected to the input IP , and a collector connected to the first power supply terminal V_{DD} ; and a voltage source V_5 connected between the base of the transistor T_9 and the second power supply terminal V_{SS} .

Transistor T_9 functions as an input clamp for clamping an input voltage V_i at the input IP . Thus the input voltage V_i can not become lower than the voltage delivered by the voltage source V_5 minus the base-emitter voltage of transistor T_9 . As a consequence the base-emitter voltage of transistor T_3 can not become too low and thus a too low current through transistor T_3 is hereby prevented. It in fact means that input voltage V_i is reduced with a certain amount when the amplifier stage AMPST is not in the normal mode.

The voltage delivered by the voltage source V_5 is preferably dimensioned such that when the amplifier stage AMPST is in the normal mode the transistor T_9 virtually does not conduct any current. In order to achieve this it is recommended to track the voltage delivered by the voltage source V_5 over temperature effects and/or processing effects (if the amplifier stage AMPST is implemented in an IC). The voltage source V_5 can for example be implemented by stacking two "diode voltages" and a gate-source voltage of a field effect transistor. The two "diode voltages" can for instance be implemented by a so called " V_{be} multiplier".

Figure 13 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 12 in that the voltage source V_5 is not directly connected to the second power supply terminal V_{SS} but via a resistor R_4 , and in that the collector of transistor T_{3a} is not connected to the second power supply terminal V_{SS} but to a common junction of the voltage source V_5 and the resistor R_4 .

The said reduction of the input voltage V_i with a certain amount when the amplifier stage AMPST is not in the normal mode according to the electronic circuit as shown in Figure 12 in fact means a voltage variation in the input voltage V_i . Principally this

can increase the recovery time of the amplifier stage AMPST. Preferably, it should therefore be avoided. This is accomplished by the electronic circuit of figure 13. This is because the collector current of transistor T_{8a} causes a voltage drop across the resistor R_4 . As a consequence the voltage at the base of transistor T_9 is increased. Thus the needed base-emitter voltage of transistor T_9 is now realized by increasing the voltage at the base of transistor T_9 in stead of reducing the value of the input voltage V_i .

Alternatively the order of the voltage source V_5 and the resistor R_4 may be reversed. Then the collector of transistor T_{8a} should be connected to the base of the transistor T_9 .

Figure 14 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 13 in that the resistor R_2 is now represented by a series arrangement of resistors R_{2a} and R_{2b} , and in that the collector of transistor T_9 is now not connected to the first power supply terminal V_{DD} but to a common junction of the resistors R_{2a} and R_{2b} .

By this the third current path CP_3 , and thus the fold-back mode is implemented. When the amplitude of the input current I_i exceeds the further input reference level I_B (see figures 4 and 5) the transistor T_9 takes away current from the second current path CP_2 . As a consequence the value of the output current I_o decreases with further increasing value of the input current I_i . The ratio of the values of the resistors R_{2a} and R_{2b} is preferably to be determined such that the transistor T_9 will never go into saturation. It might turn out that an appropriate value of the resistor R_{2b} equals zero. So in that case the collector of the transistor T_9 is in fact connected to the common connection point of the resistor R_2 and the emitter of the transistor T_2 (see figure 13).

In order to implement the minimum fold-back mode whereby the value of the output current can not become lower than a minimum value, which minimum value is referred to as the output reference level $I_{o_{mn}}$, (see figures 4 and 5) some additional measure has to be taken. This measure could for instance be that the ratio of the values of the resistors R_{2a} and R_{2b} is chosen such that at a certain value of the output current I_o (which is the output reference level $I_{o_{mn}}$) the collector-emitter voltage of the transistor T_9 has become so low that the transistor T_9 goes into saturation, and thus its collector current can not further increase. In practice however it is not always possible to find an appropriate ratio of the values of the resistors R_{2a} and R_{2b} for getting this result without conflicting other dimensioning requirements for the amplifier stage AMPST. Furthermore, as already stated before, a

saturation situation of the transistor T_9 is not a desirable situation since it can potentially increase the recovery time of the amplifier stage AMPST.

For above mentioned reasons another measure for the implementation of the minimum fold-back mode is disclosed in the electronic circuit of figure 15.

5 Figure 15 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 14 in that it further comprises a transistor T_{10} having a base, an emitter coupled to the second current path CP_2 (in this example the emitter is connected to the collector of the transistor T_9), and a collector connected to the first power supply terminal V_{DD} ; a buffer VB3 having an input connected to the reference terminal B_{RF} , and an output; and a voltage source V_6 connected between the base of the transistor T_{10} and
10 the output of the buffer VB3.

By this the fourth current path CP_4 , and thus the minimum fold-back mode, is implemented. The voltage delivered by the voltage source V_6 is chosen to be such that when the amplitude of the output current I_o tends to become lower than the output reference level
15 $I_{o_{mn}}$, the transistor T_{10} delivers current (which value increases with further increasing value of the input current I_i) to the second current path CP_2 . As a consequence the value of the output current I_o remains approximately constant.

By the manner in which the minimum fold-back mode is implemented in the circuit according to figure 14, at the same time also a minimum value $I_{o_{mn}}$ of the output
20 current I_o is implemented in the normal mode. For some applications this is not a problem.

Figure 16 shows an electronic circuit comprising an amplifier stage AMPST which differs from the one shown in figure 15 in that it further comprises a resistor R_5 connected in between the output of the buffer VB3 and the voltage source V_6 ; and in that the second control means SCM further comprises a bipolar transistor T_{8c} having a base connected
25 to the base of the transistor T_{8a} , an emitter connected to the emitter of the transistor T_{8a} , and a collector connected to a common connection point of the voltage source V_6 and the resistor R_5 . Optionally (not shown in figure 16) an additional voltage source may be arranged in series with the buffer VB3.

When the amplifier stage is not in the normal mode the transistor T_{8c} delivers a
30 current. As a consequence a voltage across the resistor R_5 is created. This increases the voltage at the base of transistor T_{10} . As a consequence the transistor T_{10} conducts current during the minimum fold-back mode. When however the amplifier stage is in the normal mode the transistor T_{8c} does not deliver any current. As a consequence there is virtually no

voltage across the resistor R_5 , and thus the transistor T_{10} does not conduct any current (if the value of the voltage delivered by the voltage source V_6 is not chosen too large).

By this the fourth current path CP_4 is inactive in the normal mode, and thus the value of output current is, in the normal mode, not restricted to the minimum value $I_{o_{mn}}$.

5 It is to be emphasized that many variations can be made for the implementations of the disclosed electronic circuits. For instance, P-type transistors may be replaced by N-type transistors and vice versa. It may then be necessary to adapt the polarity of the voltages and currents delivered by the voltage sources and the current sources, respectively. Further other types of transistors may be suitable. Basically all the indicated
10 types of transistors can be replaced by other types of transistors. For instance transistors T_1 and T_2 may be replaced (both) by field effect transistors. The transistor M_1 may be replaced by a bipolar transistor. The current mirror CM can also be implemented by more sophisticated current mirrors, for instance current mirrors which additionally use cascode transistors (for cascoding the transistors T_1 and T_2), or which are provided with feedback
15 means for the purpose of reducing the input impedance and/or increasing the output impedance.

Further the electronic circuits may be implemented in an IC or may be fully/partly constructed with discrete components.

20 The electronic circuits can be applied in all kinds of apparatus and systems which need means to limit an output signal and which need a very short recovery time when the relatively strong input signal is reduced to a relatively weak input signal.

CLAIMS:

17. 10. 2002

(83)

1. An electronic circuit comprising an amplifier stage (AMPST) having an input (IP) for receiving an input signal (I_i) and an output (OP) for supplying an output signal (I_o), whereby, during operation, the strength of the output signal (I_o) increases in response to an increasing strength of the input signal (I_i) as long as the strength of the input signal (I_i) has not exceeded an input reference level (I_A), characterized in that the strength of the output signal (I_o) is approximately kept constant when the strength of the input signal (I_i) has exceeded the input reference level (I_A) but has not exceeded a further input reference level (I_B), and that the strength of the output signal (I_o) decreases in response to an increasing strength of the input signal (I_i) when the strength of the input signal (I_i) has exceeded the further input reference level (I_B).
5
2. An electronic circuit according to claim 1, characterized in that the strength of the output signal (I_o) can not become lower than an output reference level ($I_{o_{\min}}$) when the strength of the input signal (I_i) has exceeded the further input reference level (I_B).
15
3. An electronic circuit according to claim 1 or 2, characterized in that the further input reference level (I_B) is approximately equal to the input reference level (I_A).
20
4. An electronic circuit according to claim 1, 2, or 3, characterized in that the input signal (I_i) is an input current (I_i), and the output signal (I_o) is an output current (I_o).
25
5. An electronic circuit according to claim 4, characterized in that the amplifier stage (AMPST) comprises a first current path (CP_1) coupled between the input (IP) and a common node (cn); a second current path (CP_2) coupled between the output (OP) and the common node (cn); first control means (FCM) coupled between the input (IP) and the common node (cn), for controlling a (V_{cn}) voltage on the common node (cn) and for supplying a current (I_2) to the common node (cn), the first control means (FCM) comprising limiting means (LMT) for limiting the current (I_2) to the common node (cn) when the strength of the input signal (I_i) has exceeded the input reference level (I_A); and second control

means (SCM) for supplying a compensation current (I_{cmp}) to the input (IP) when the strength of the input signal (I_i) has exceeded the input reference level (I_A).

6. An electronic circuit according to claim 5, characterized in that the amplifier stage (AMPST) further comprises a third current path (CP_3) having a first side coupled to the input (IP), and a second side coupled to the second current path (CP_2) for taking away current from the second current path (CP_2) so that the strength of the output current (I_o) decreases in response to an increasing strength of the input signal (I_i) when the strength of the input signal (I_i) has exceeded the further input reference level (I_B).

7. An electronic circuit according to claim 6, characterized in that the amplifier stage (AMPST) further comprises a fourth current path (CP_4) coupled to the second current path (CP_2) for supplying current to the second current path (CP_2) in order to avoid that the output current (I_o) can be lower than the output reference level ($I_{o_{\text{ref}}}$) when the strength of the input signal (I_i) has exceeded the further input reference level (I_B).

8. An optical/magneto-optical disc recording apparatus comprising a light source (LS) for storing data on a disk (DSK), and light receiving means (PHDS) for the detection of data from the disk (DSK), characterized in that the apparatus comprises an electronic circuit as defined in any of the preceding claims, whereby the input signal (I_i) of the amplifier stage (AMPST) is responsive to a signal (A; B; C; D) delivered by the light receiving means (PHDS).

9. A method whereby an input signal (I_i) is being converted to an output signal (I_o), and whereby the strength of the output signal (I_o) increases in response to an increasing strength of the input signal (I_i) as long as the strength of the input signal (I_i) does not exceed an input reference level (I_A), and whereby the strength of the output signal (I_o) is being kept approximately constant when the strength of the input signal (I_i) exceeds the input reference level (I_A) but does not exceed a further input reference level (I_B), and whereby the strength of the output signal (I_o) decreases in response to an increasing strength of the input signal (I_i) when the strength of the input signal (I_i) exceeds the further input reference level (I_B).

10. A method according to claim 9, characterized in that the strength of the output signal (I_o) does not become lower than an output reference level ($I_{o_{mn}}$) when the strength of the input signal (I_i) exceeds the further input reference level (I_B).

ABSTRACT:

17. 10. 2002

(83)

An electronic circuit is provided which can autonomously handle an input current (I_i) having a relatively large dynamic range without being overdriven. The electronic circuit comprises an amplifier stage (AMPST) having an input (IP) for receiving the input current (I_i) and an output (OP) for supplying an output current (I_o), whereby, during operation, the strength of the output current (I_o) increases in response to an increasing strength of the input current (I_i) as long as the strength of the input current (I_i) has not exceeded an input reference level. The strength of the output current (I_o) is approximately kept constant when the strength of the input current (I_i) has exceeded the input reference level but has not exceeded a further input reference level. The strength of the output current (I_o) decreases in response to an increasing strength of the input current (I_i) when the strength of the input current (I_i) has exceeded the further input reference level. The amplifier stage (AMPST) may comprise a current mirror (CM) having an input which forms the input (IP), an output which forms the output (OP), and a common node (cn). The amplifier stage (AMPST) further comprises first control means (FCM) having an input connected to the input (IP), and an output connected to the common node (cn). The first control means (FCM) controls a current (I_2) to the common node (cn) and a voltage (V_{cn}) at the common node (cn). The first control means (FCM) comprises limiting means (LMT) for limiting the current (I_2) when the value of the input current (I_i) has exceeded the input reference level. Then both the input and the output currents (I_i and I_o) are limited. In order to avoid a saturation situation of a current source (I_s) which supplies a current (I) to the input (IP) the amplifier stage (AMPST) may comprise second control means (SCM) for supplying a compensation current (I_{cmp}) to the input (IP) when the input signal (I_i) has exceeded the input reference level. The current mirror (CM) comprises first (CP_1) and second (CP_2) current paths which form the core of the current mirror (CM) which is generally known. The decrease in response to an increasing strength of the input current (I_i) when the strength of the input current (I_i) has exceeded the further input reference level, is implemented by a third current path (CP_3) which takes away current from the second current path (CP_2). Optionally, to avoid that the value of the output current (I_o) can become too low, a fourth current path (CP_4) can be implemented which puts current to the second current path (CP_2). The inventive electronic

circuit can be advantageously applied in all electronic systems (like CD-apparatus) which need means to limit a maximum output signal.

Figure 8

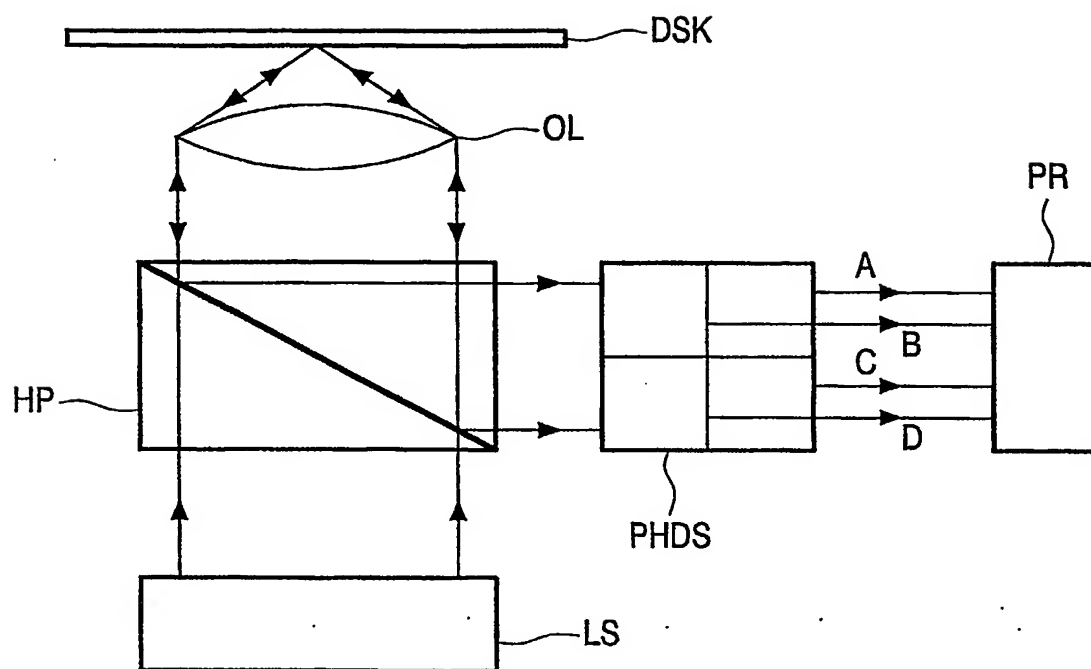


Fig.1

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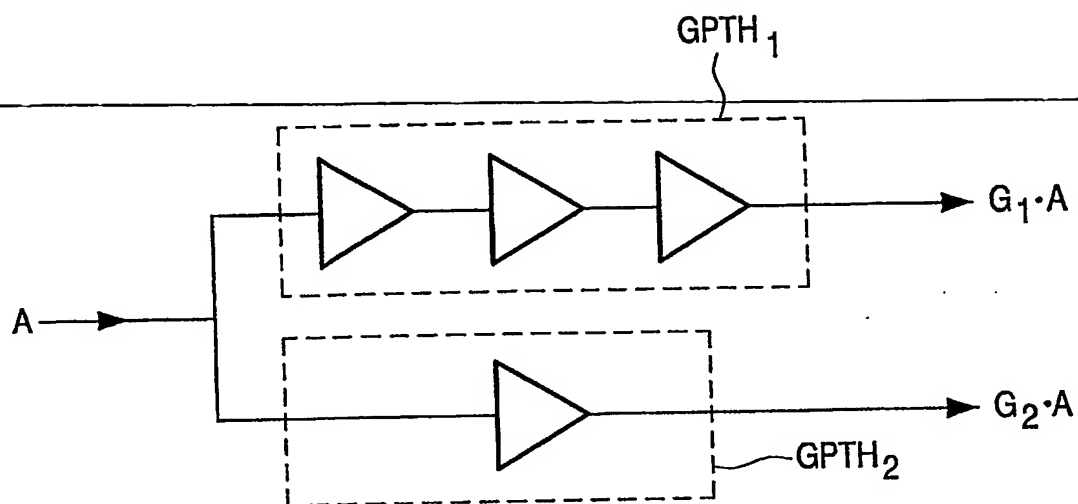


Fig.2

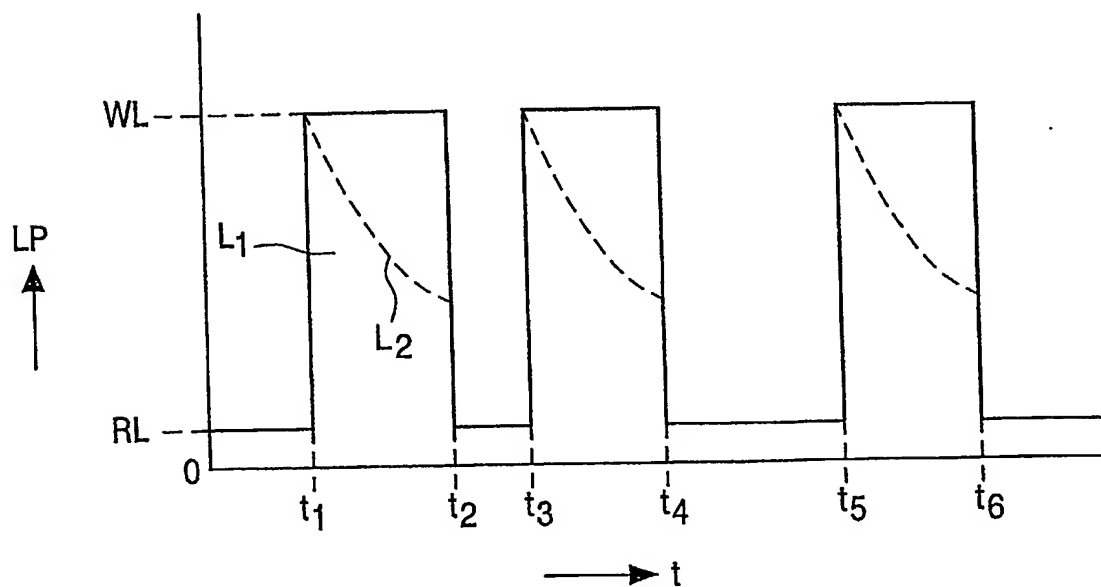


Fig.3

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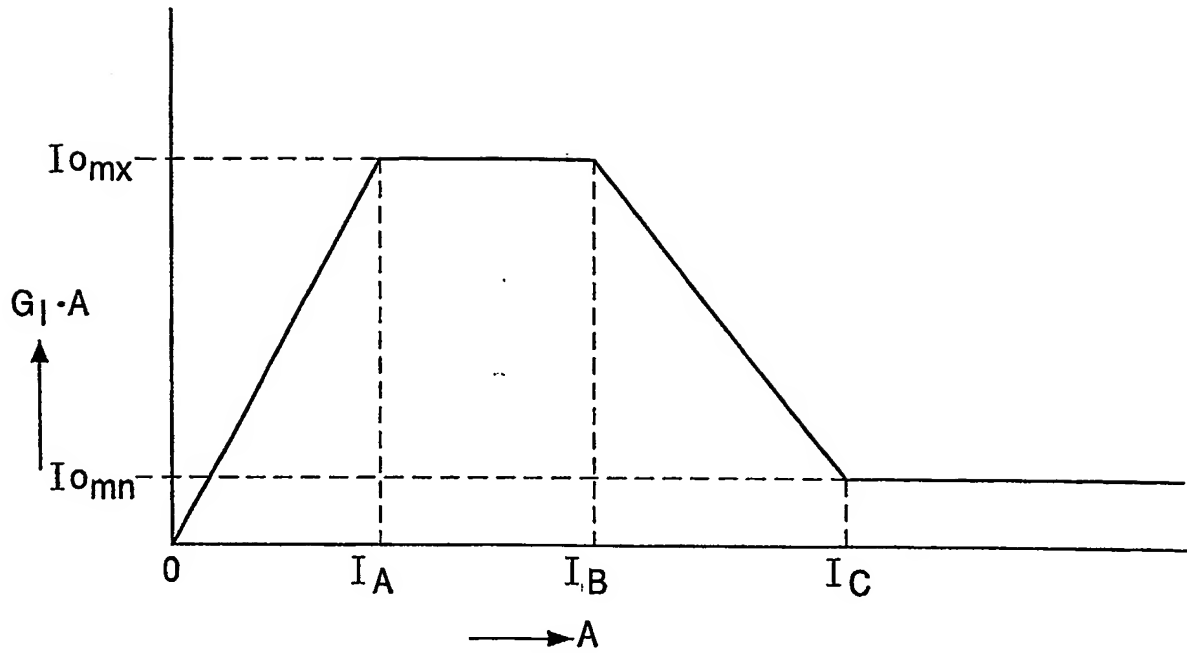


Fig.4

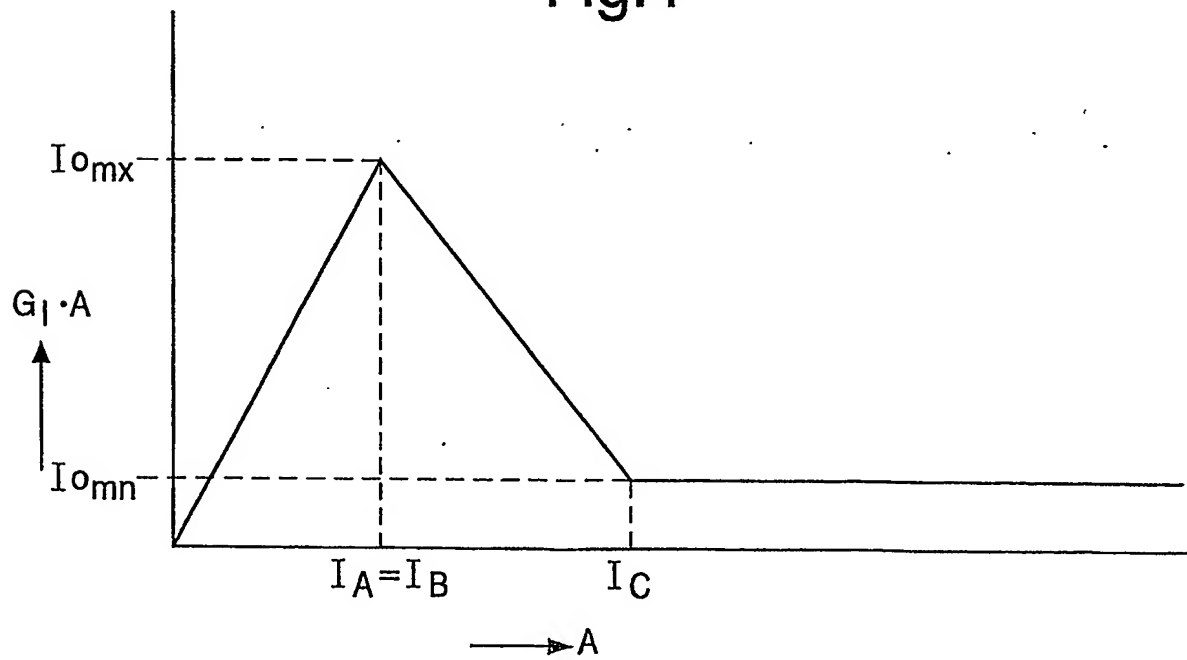


Fig.5

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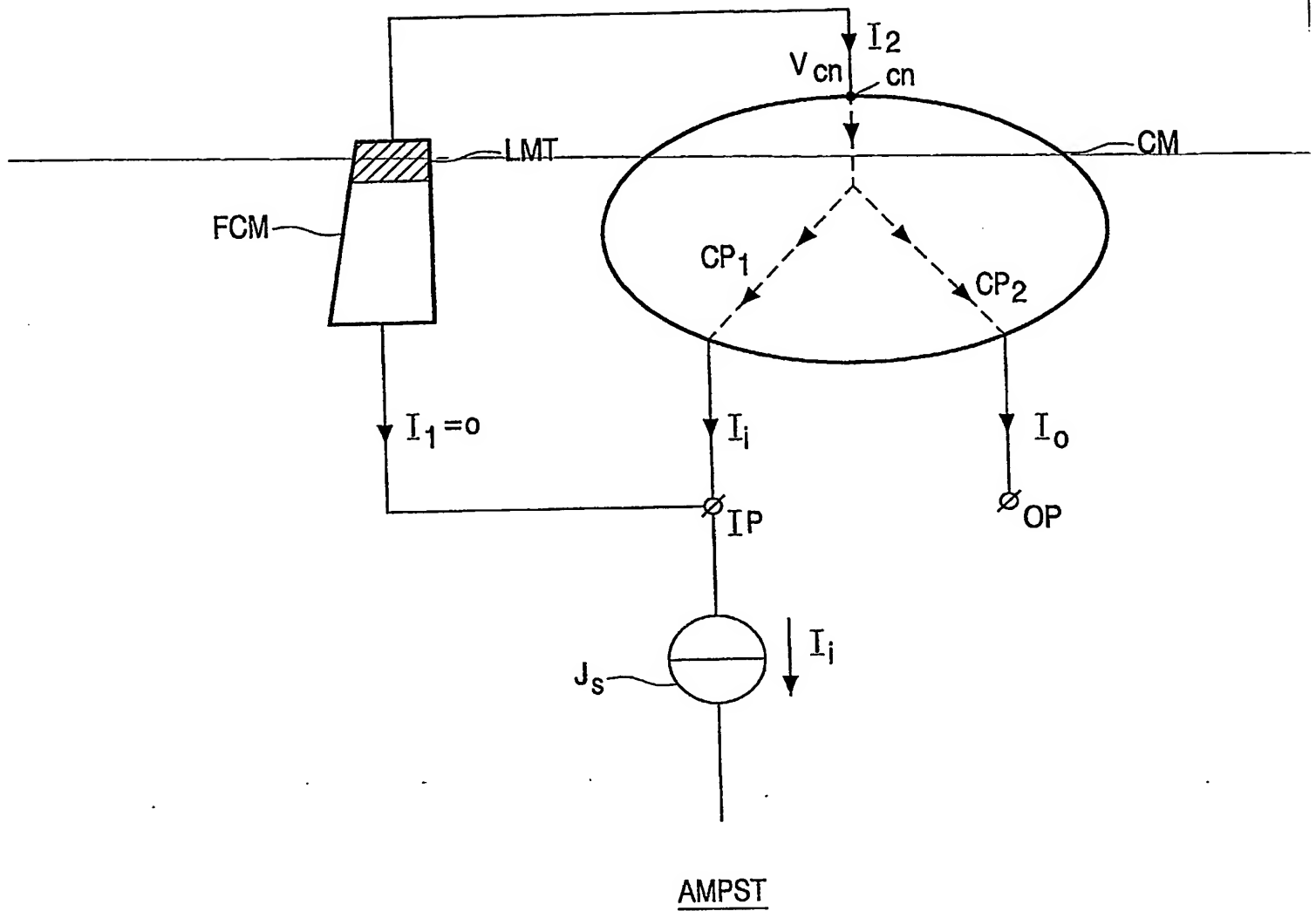


Fig.6

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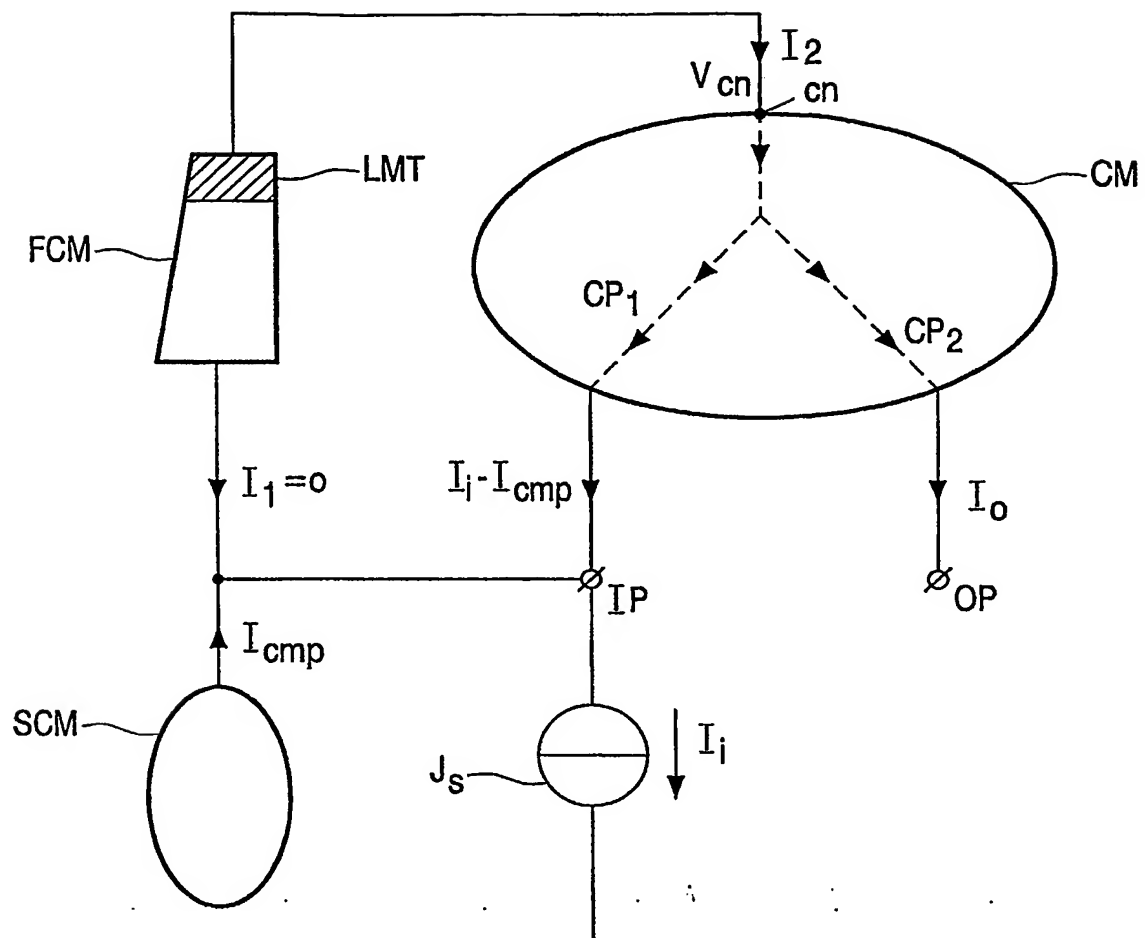
AMPST

Fig.7

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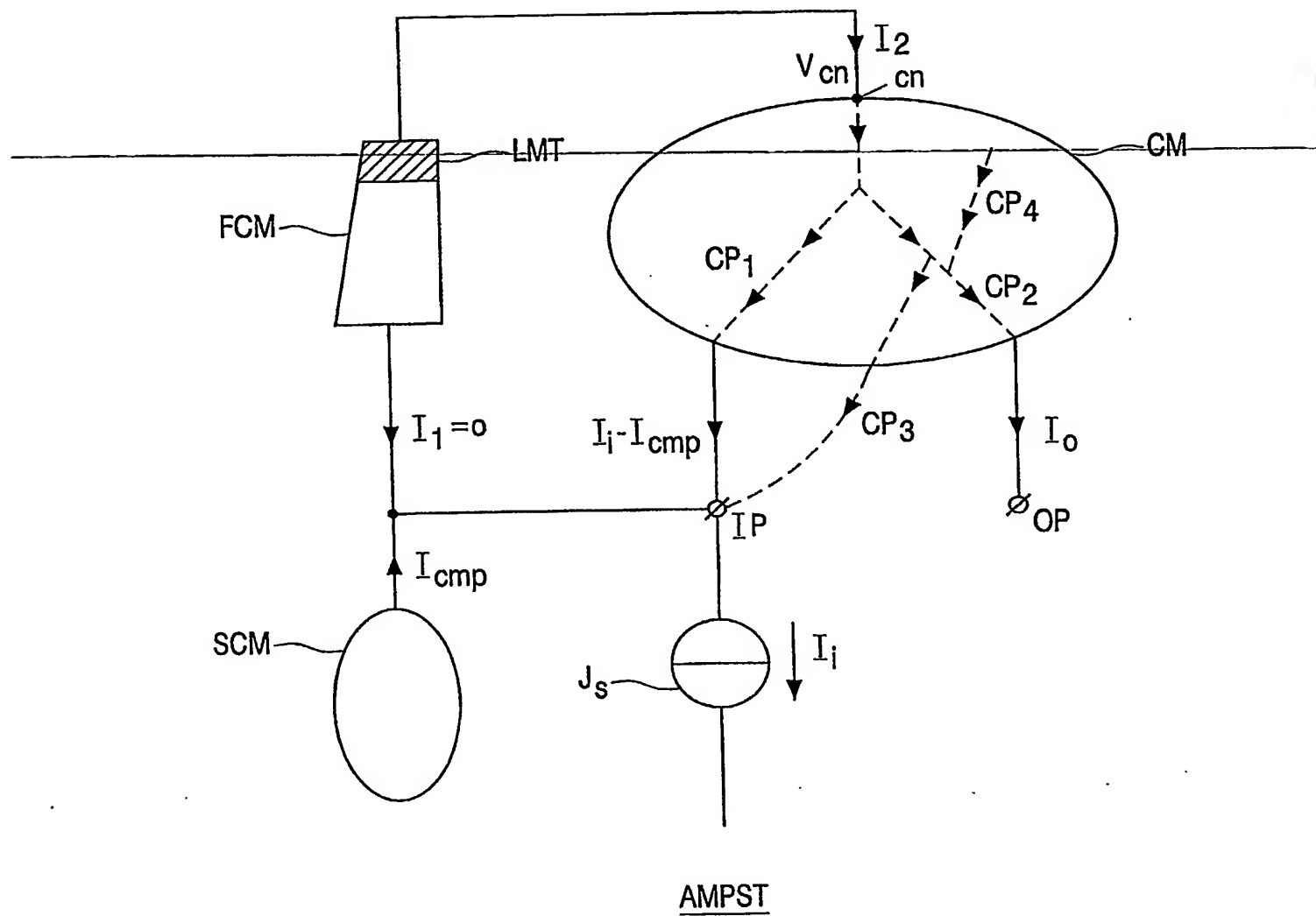


Fig.8

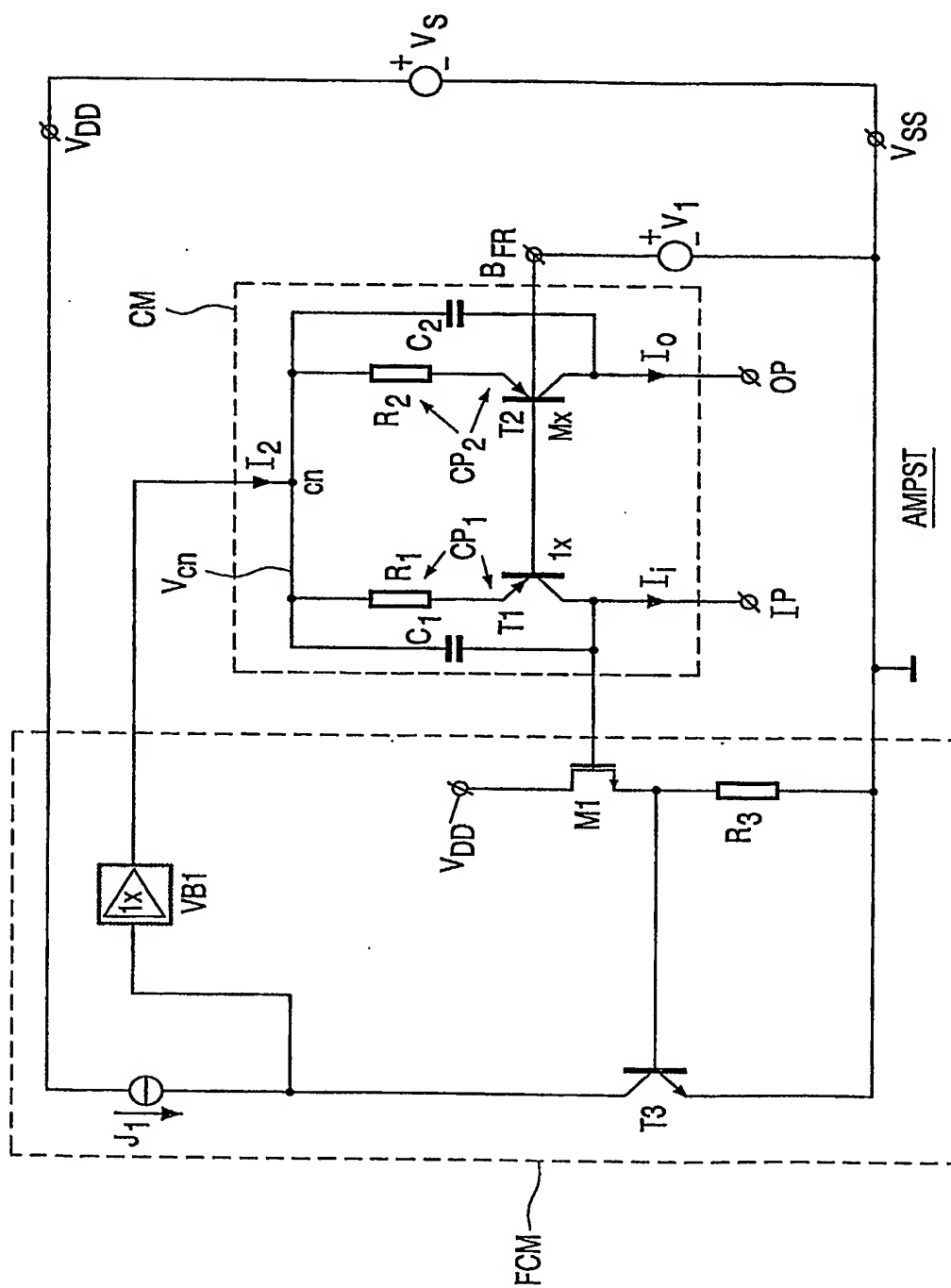


Fig. 9

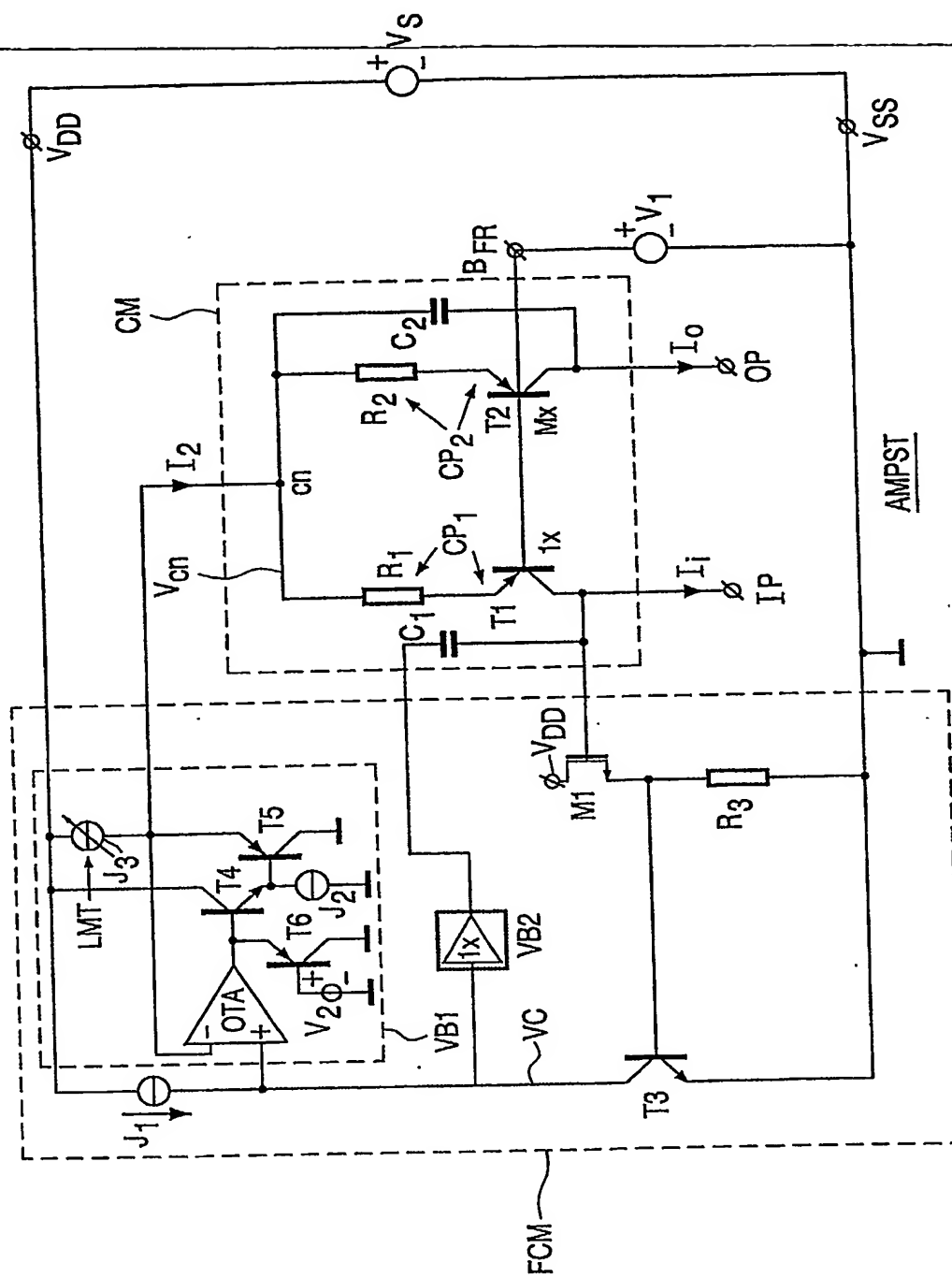


Fig.10

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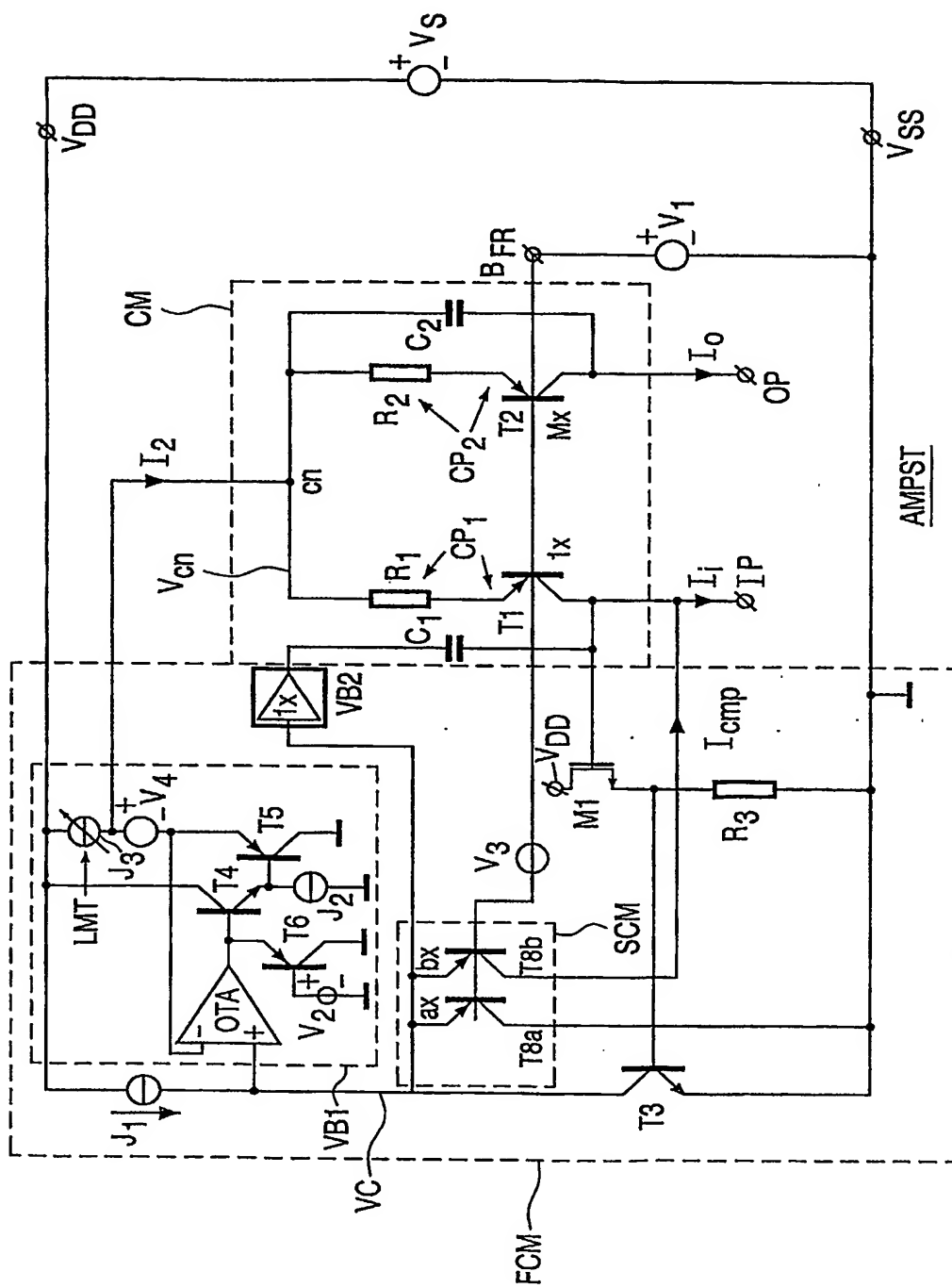


Fig.11

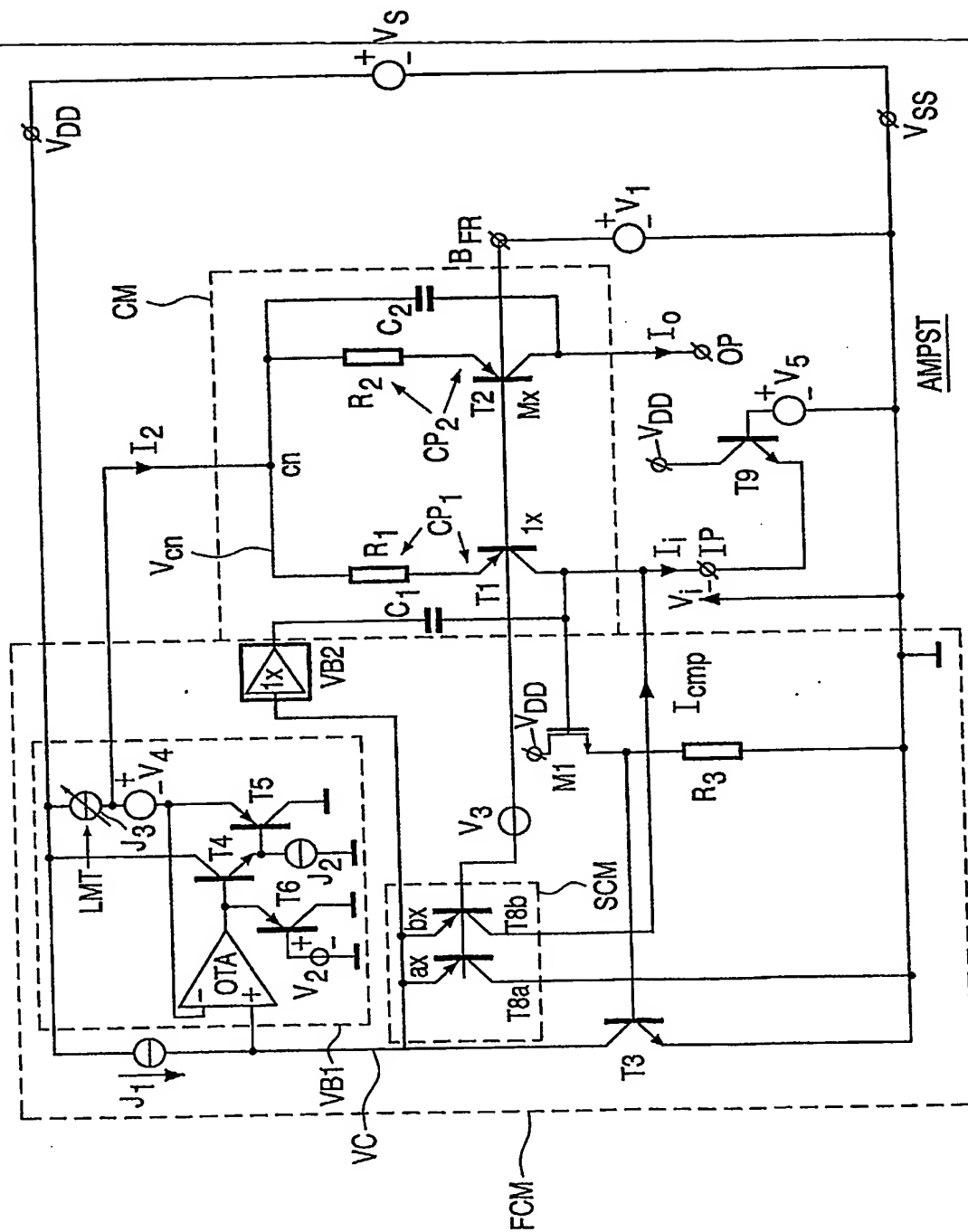


Fig.12

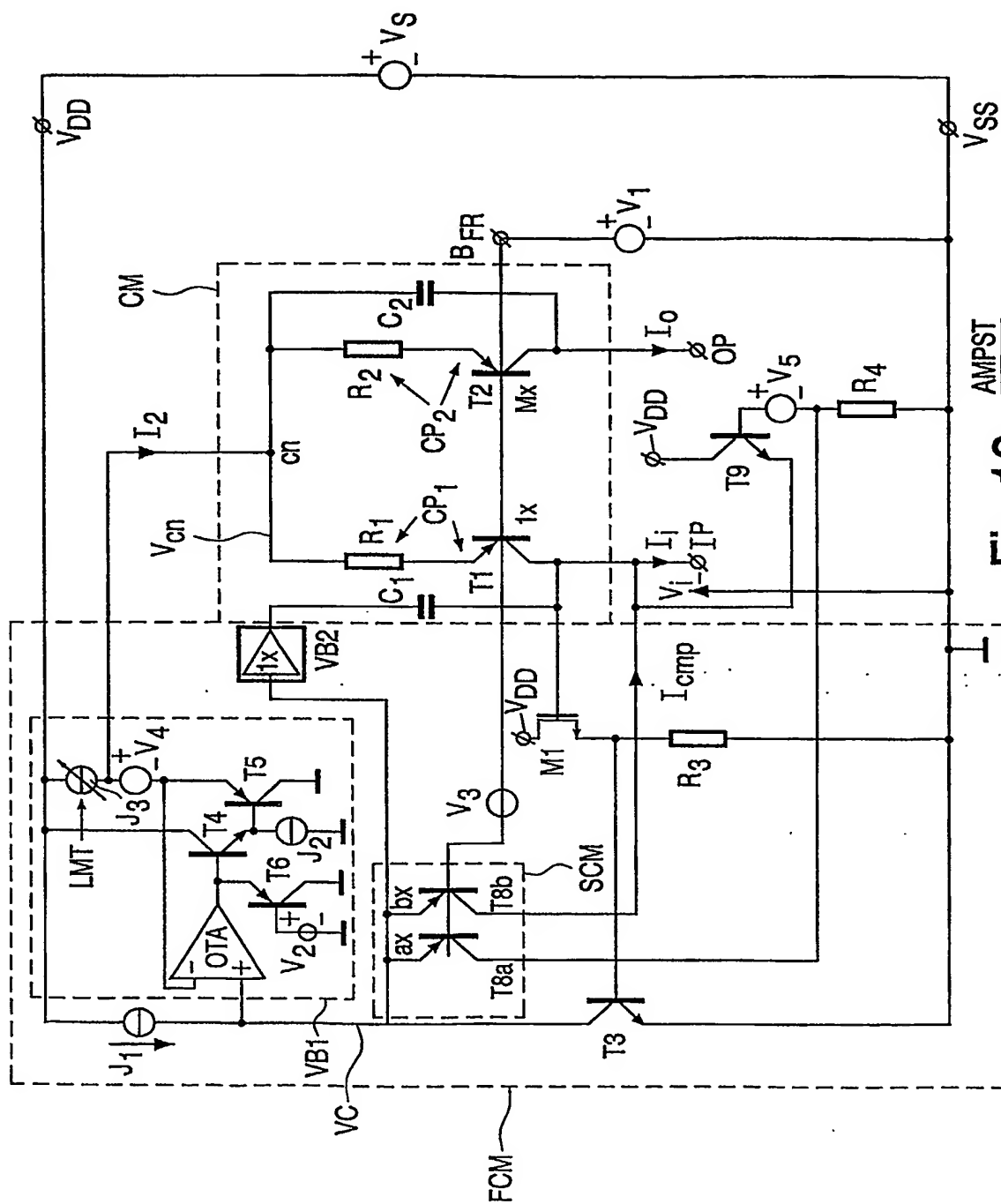


Fig. 13

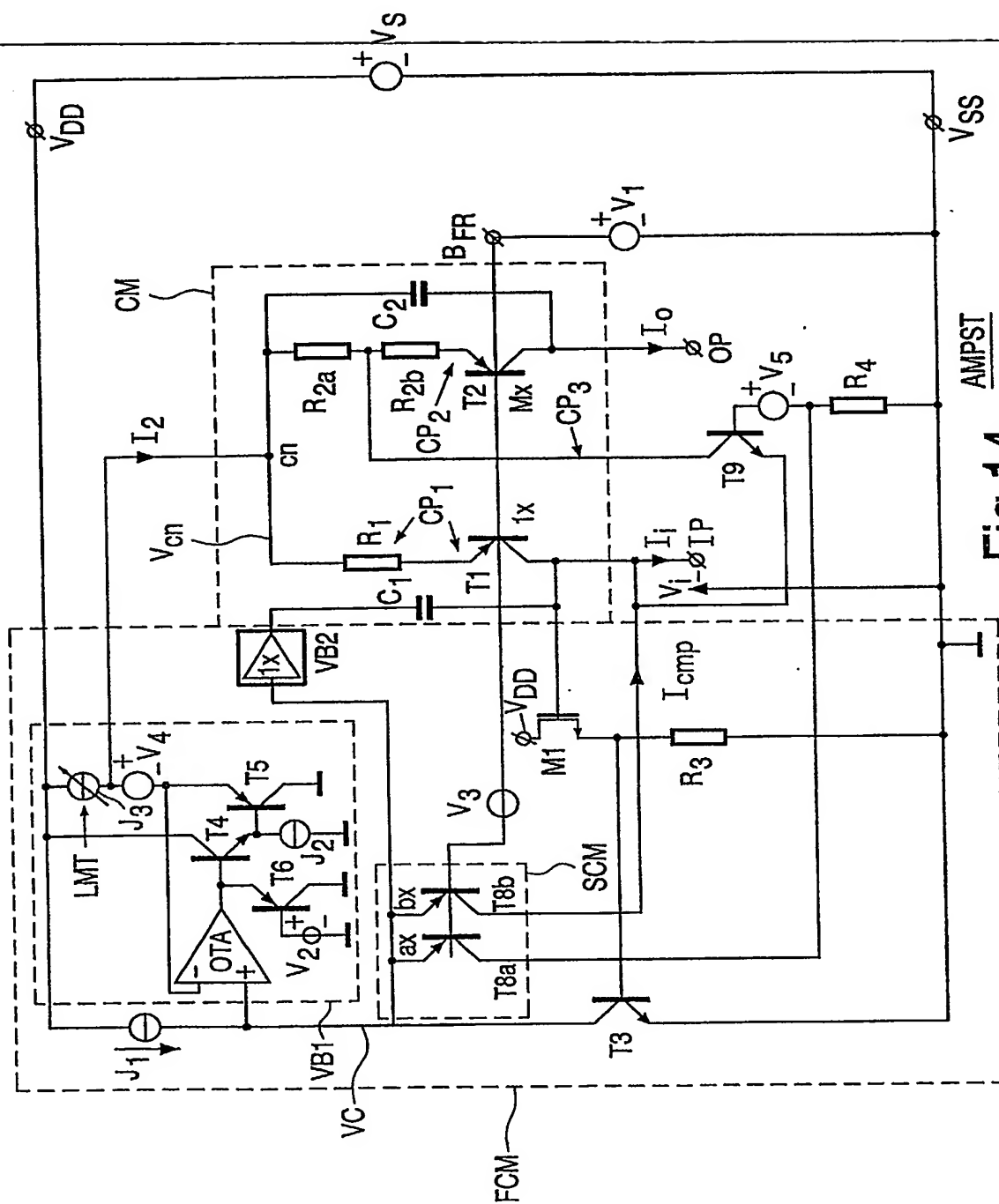


Fig.14

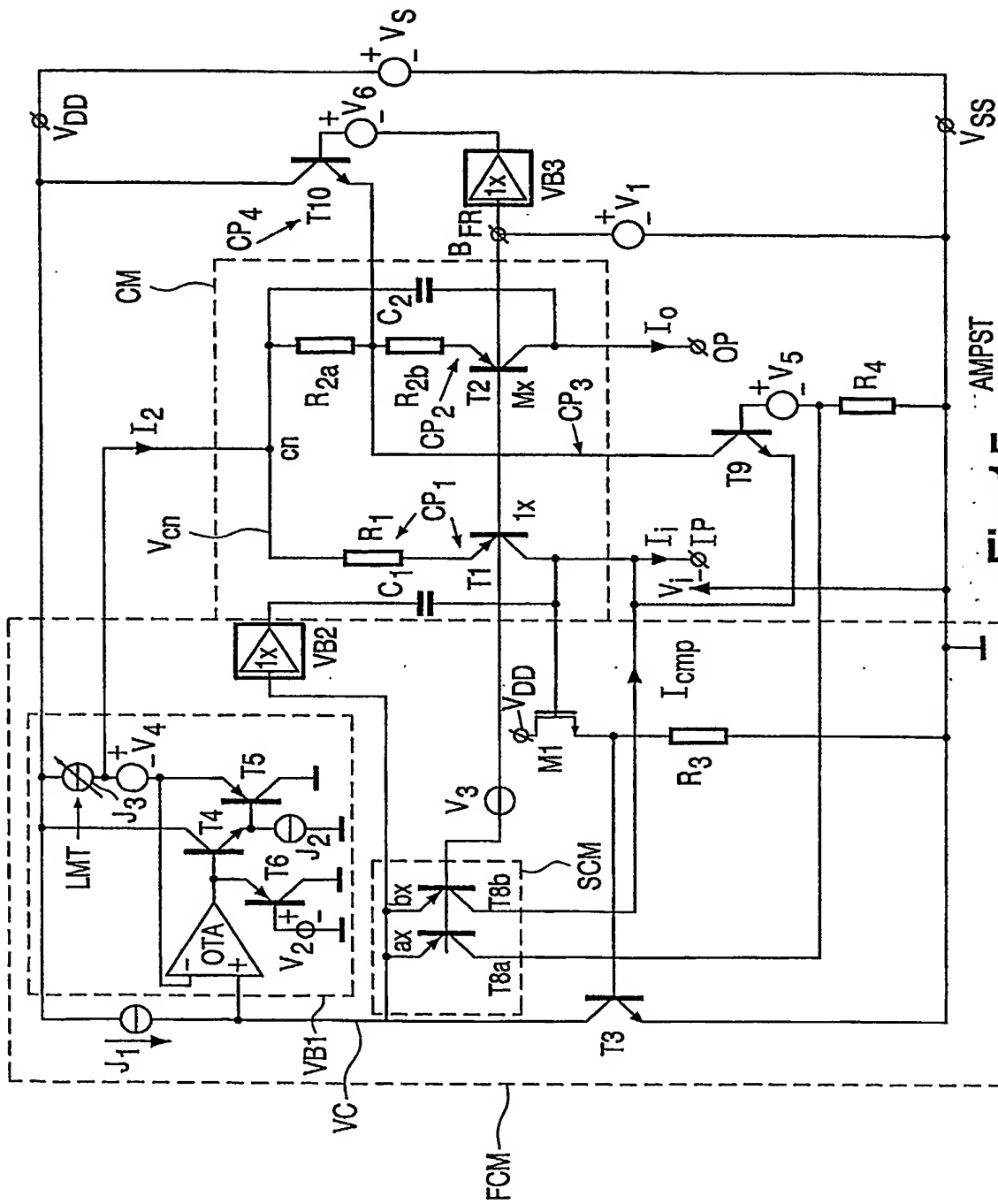


Fig.15

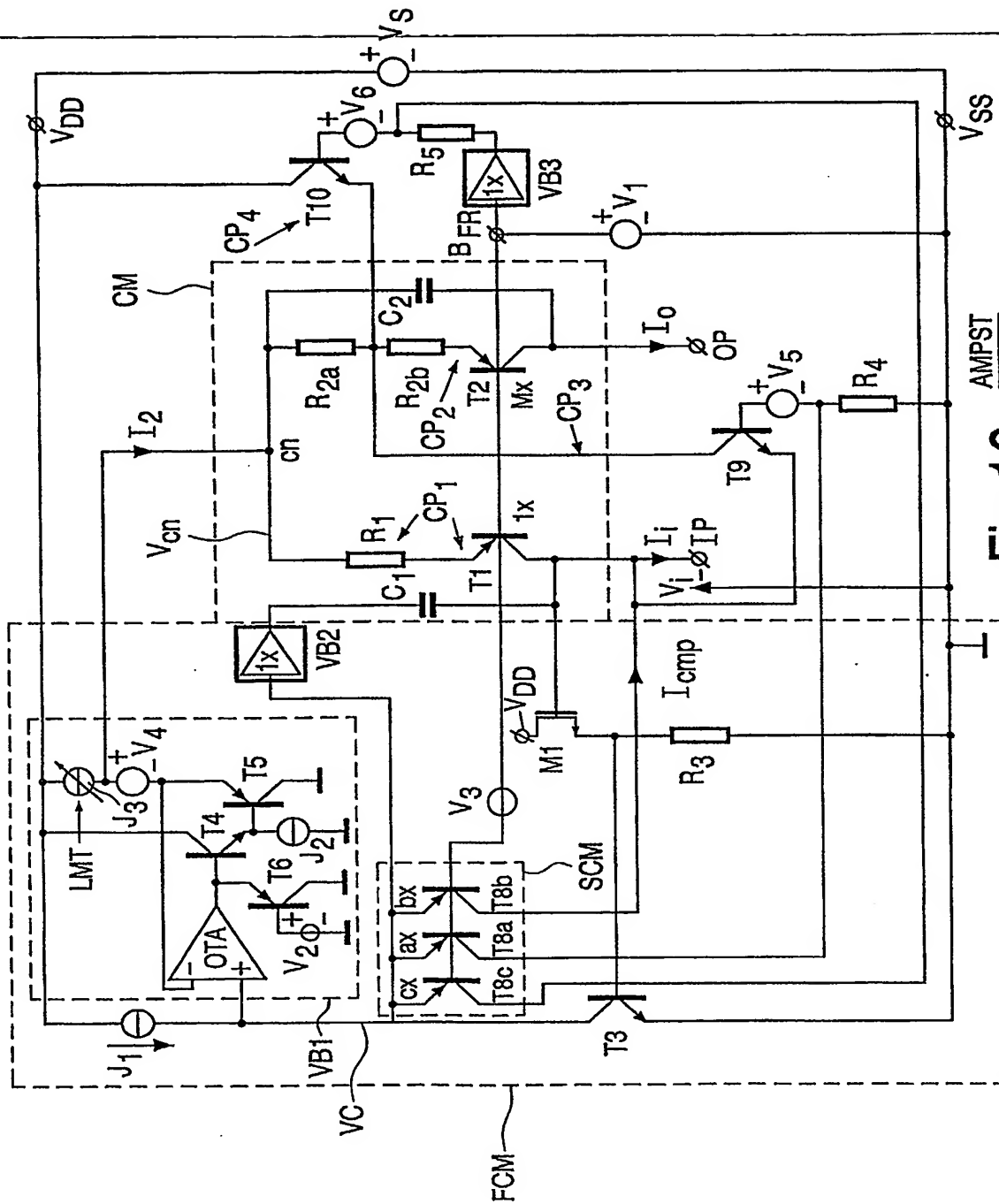


Fig.16

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